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AGRICULTURE

Dust Collection Fan VSD

SWPR005-01

CONTENTS

MEASURE NAME

VSD on Dust Collection Fan

STATEWIDE MEASURE ID

SWPR005-01

TECHNOLOGY SUMMARY

The measure outlined in this work paper is to install Variable Speed Drives (VSD) on existing fans for the dust collection fan systems, commonly known as baghouses, for Agricultural and Industrial customers. The VSD will reduce the speed of the fan based on the load of the dust collection system and the air velocity required by the system. Controls will be needed in the form of pressure transducers, flow sensors, or velocity sensors to provide feedback to the VSD during operation.

Baghouses are used in buildings and processes to remove dust, particulates, or other air suspended material from a specific area or equipment. These systems are used by a wide variety of customers for harvest, processing, and manufacturing of products. A typical baghouse uses a blower or fan to provide suction to the system. The collected air with suspended particulate is pulled through ducting to the entrance of the baghouse to be filtered. The filters within the baghouse use compressed air, vibrations, or a combination of both to periodically clean the filters. After filtering, the air stream is vented to the atmosphere or away from the serviced area.

During the design of a baghouse, the velocity (feet per minute) of the airstream is selected to ensure the particulate, dust, or other air suspended object is removed by the baghouse and does not settle in the ducting. Within a baghouse system, the main duct entering the baghouse typically contains the largest diameter duct and therefore the lowest airstream velocity. Lighter particulates have a lower minimum velocity while heavier particulates need higher minimum velocities to operate effectively. The following table is a sample of velocity requirements based on particulates:

Particulate	Minimum Velocity (Feet/min)		
	Min	Average	Max
Gases	1,000	1,500	2,000
Fumes	2,000	2,250	2,500
Oil Mist	2,000	2,250	2,500
Very Fine Light Dust	2,500	2,750	3,000
Dry Dust and Powders	3,500	3,750	4,000
Typical Industrial Dust	3,000	3,500	4,000
Heavy Dust	4,000	4,250	4,500
Heavy or Moist	4,500	4,500	4,500

The air flow demand for a baghouse is dependent on the quantity of pick-up points and their individual flow requirements to properly ventilate the area or equipment. The baghouse filters are then sized based on the air flow requirements with additional capacity for future addition onto the system or increase at the pickups. The baghouse fans are selected based on both the necessary airflow requirements of the system and the static pressure based on the geometry and distance of the ducting. The use of a variable speed drive on a baghouse fan will allow the system to modulate based on either air flow or static pressure requirements. For baghouse systems that do not have variable flow and pressure requirements, a variable speed drive will help ensure that the fan operates at the minimum speed required to keep particulates in suspension. Based on conversations with baghouse vendors, a typical steady state system will have energy savings potential stemming from fan optimizing system capacity based on end use requirements. For systems with variable pick-ups or automatic shut off gates to equipment, the static pressure and airflow needs will vary significantly through the systems operation. During conversations with vendors and customers, systems with fan motors 50 horsepower (hp) or less typically have a single pick-up with no automatic shut-off gates.

MEASURE CASE DESCRIPTION

The measure case is to add a variable speed drive (VSD) on an existing fan of sizes from 10-hp to 50-hp. See table below for measure descriptions.

Measure Codes	Measure Name
SWPR005-01A	Dust Collection Fan VSD (10hp motor)
SWPR005-01B	Dust Collection Fan VSD (15hp motor)
SWPR005-01C	Dust Collection Fan VSD (20hp motor)
SWPR005-01D	Dust Collection Fan VSD (25hp motor)
SWPR005-01E	Dust Collection Fan VSD (30hp motor)
SWPR005-01F	Dust Collection Fan VSD (40hp motor)
SWPR005-01G	Dust Collection Fan VSD (50hp motor)

BASE CASE DESCRIPTION

The base case is an existing fixed speed fan with rated individual motor capacity from 10-hp to 50-hp. The base case fan will either operate continuously or have on/off controls. Fan motors must not be two-speed or have an existing VSD.

CODE REQUIREMENTS

There is no California State or National energy codes that are applicable to VSD being installed on dust collection fans for Agricultural or Industrial processes. Depending on the customer and their processes, there may be applicable OSHA or NFPA regulations that set limits on the velocity requirements for safety standards.

NORMALIZING UNIT

The normalizing unit is per horsepower (hp).

PROGRAM REQUIREMENTS

Measure Implementation Eligibility

The following customer and system specifications need to be met to be eligible under this work paper:

- The PG&E customer must be within the following NAICS Code:
    - 111000 to 112990
    - 311000 to 339999
    - 211120 to 213115
- The existing baghouse, fan, and motor need to be in proper operating condition

- The baghouse fan's motor must be compatible with a VSD[1]
- There must be no previous VSD or failed VSD installed on the baghouse existing fan motor
- The installed VSD must be controlled based on static pressure, air flow rate (CFM), or velocity of the airstream in a feedback loop
- The minimum fan size has to be 10-hp and not to exceed 50-hp

Implementation Eligibility

Measure Application Type	Delivery Type	Sector
Add-on equipment	DnDeemDI	Ag, Ind
Add-on equipment	DnDeemed	Ag, Ind

Eligible Products

The variable speed drive (VSD) must be used to vary the speed of the fan automatically based on load conditions and the corresponding air velocity required.

The VSD is recommended to meet requirements as specified by IEEE Standard 519-2014 [A].

The customer must have an existing electrically operated fixed speed fan installed on site or plans to install a new electrically operated fixed speed fan.

Eligible Building Types

Customers must be within the following NAICS Code:

- 111000 to 112990
- 311000 to 339999
- 211120 to 213115

Eligible Climate Zones

The measure is applicable in all California climate zones. The measure is weather independent.

PROGRAM EXCLUSIONS

This measure cannot be used for the following fan applications:

- HVAC fan
- Individual fan motors smaller than 10-hp or bigger than 50-hp
- Fan motors must not be two-speed or have an existing VSD
- This measure is downstream and/or direct install only.

DATA COLLECTION REQUIREMENTS

There are no data collection requirements.

[1] Motors that are compatible with VSDs vary based on motor manufactures. Compatible motors may be labeled as inverter duty, VSD ready, or have insulation classification F.

USE CATEGORY

ProcDist

ELECTRIC SAVINGS (kWh)

The measure outlined in this workpaper will reduce the electrical energy consumption and demand of a baghouse fan by varying the speed of the motor to meet the airflow or pressure requirements. The baseline and installed energy consumption for each measure varies based on the horsepower of the baghouse fan motor. Based on a survey of agricultural customers who utilize baghouses, it was determined that, on aggregate, seasonal and non-seasonal customers operate 4,806 hours per year[2]. The following calculation is used to quantify the baseline power draw for baghouse fan motor:

$$kW_{baseline} = HP_{fan} \times LF \times C_1 \times (1/EFF)$$

where,

HP_{fan}	=	Motor Nameplate Power, HP
LF	=	Load Factor, 66% for Fans[3]
C_1	=	Conversation Factor, 0.756 kW per HP
EFF	=	NEMA Premium Motor Efficiency

The proposed power draw of a baghouse fan motor with a VSD is dependent on the average operating speed when in use. In order to determine the average operating speed, a survey of baghouse vendors was performed to determine the actual velocity of the air stream based on typical baghouse capacities (CFM) and duct diameters (inches) for a various fan size (hp). It should be noted that when systems are designed to their specific requirements for air flow and velocity, the use of a VSD to control the fan will result in low to no energy savings. Based on the vendor survey, most existing systems are operating at less than the designed capacity and therefore have opportunity to reduce the fan speed and yield energy savings. The proposed velocity of the air stream is quantified using a weighted average of minimum velocities over all surveyed customers. Using the vendor survey and proposed velocity, the average operating speed can be quantified to determine the proposed power draw. The following formula is used to quantify the proposed power draw:

$$kW_{prop.} = HP_{fan} \times LF \times C_1 \times (1/EFF) \times OS^{2.7} \times (1/EFF_{VSD})$$

where,

HP_{fan}	=	Motor Nameplate Power, HP
LF	=	Load Factor, 66% for Fans
C_1	=	Conversation Factor, 0.756 kW per HP
EFF	=	NEMA Premium Motor Efficiency
OS	=	Average Operating Speed of the VSD[4]
EFF_{VSD}	=	Efficiency of the VSD, 97%[5]

The table below is a summary of the Energy Savings and Demand Reduction by motor size:

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[2] The annual operating hours are derived from the customer survey between NAICS codes 111000 to 112990 and 31100 to 312140. For Industrial customers, it is assumed that the annual operating hours will on average be greater than 4,806 hours per year. For this workpaper, these operating hours will be used for all customers within the specific NAICS codes to be conservative on energy and demand savings.

[3] Based on DOE's "Determining Electric Motor Load and Efficiency", the average motor load is 75%. Using ERI's experience for fans and to generate a conservative approach, 66% motor load has been applied.

[4] The proposed operating speed is a weighted average based on the expected minimum speeds for various agricultural customers. The operating speed used would be conservative or comparable for industrial customers.

[5] https://www.energy.gov/sites/prod/files/2014/04/f15/motor_tip_sheet11.pdf

Fan Motor HP	Baseline Energy Use (kWh/yr)	Baseline Peak Demand (kW)	Proposed Energy Use (kWh/yr)	Proposed Peak Demand (kW)	Energy Saving (kWh/yr)	Peak kW Demand Saving (kW)
10 HP	25,946.1	5.40	23,267.5	4.84	2,678.6	0.56
15 HP	38,559.7	8.02	25,842.6	5.38	12,717.1	2.65
20 HP	50,915.2	10.59	31,816.4	6.62	19,098.8	3.97
25 HP	63,235.8	13.16	28,762.0	5.98	34,473.7	7.17
30 HP	75,680.7	15.75	38,361.7	7.98	37,319.0	7.77
40 HP	100,585.9	20.93	50,676.0	10.54	49,909.8	10.38
50 HP	125,200.1	26.05	84,051.5	17.49	41,148.6	8.56

PEAK ELECTRIC DEMAND REDUCTION (kW)

The average demand reduction is the difference between the baseline and measure case input demand. For more details please see the “Electric Savings” section above.

$$kW_{baseline} = HP_{fan} \times LF \times C_1 \times (1/EFF)$$

where:

- HP_{fan} = Motor Nameplate Power, HP
- LF = Load Factor, 66% for Fans[6]
- C_1 = Conversation Factor, 0.756 kW per HP
- EFF = NEMA Premium Motor Efficiency

$$kW_{proposed} = HP_{fan} \times LF \times C_1 \times (1/EFF) \times OS^{2.7} \times (1/EFF_{VSD})$$

where:

- HP_{fan} = Motor Nameplate Power, HP
- LF = Load Factor, 66% for Fans
- C_1 = Conversation Factor, 0.756 kW per HP
- EFF = NEMA Premium Motor Efficiency
- OS = Average Operating Speed of the VSD[7]
- EFF_{VSD} = Efficiency of the VSD, 97%[8]

GAS SAVINGS (THERMS)

Not applicable.

LIFE CYCLE

Effective useful life (EUL) is an estimate of the median number of years that a measure installed through a program is still in place and operable. Remaining useful life (RUL) is an estimate of the median number of years that a technology or piece of equipment replaced or altered by an energy efficiency program would have remained in service and operational had the program intervention not caused the

[6] Based on DOE’s “Determining Electric Motor Load and Efficiency”, the average motor load is 75%. Using ERI’s experience for fans and to generate a conservative approach, 66% motor load has been applied.

[7] The proposed operating speed is a weighted average based on the expected minimum speeds for various agricultural customers. The operating speed used would be conservative or comparable for industrial customers.

[8] https://www.energy.gov/sites/prod/files/2014/04/f15/motor_tip_sheet11.pdf

replacement or alteration. The RUL is only applicable to the first baseline period for a retrofit measure with an applicable code baseline.

As per Resolution E-4807, the California Public Utilities Commission (CPUC) defined the EUL of an add-on equipment as the lesser of the EUL of the measure itself or the RUL of the host equipment.[1] The methodology to calculate the RUL conforms with Version 5 of the Energy Efficiency Policy Manual, which recommends "one-third of the effective useful life in DEER as the remaining useful life until further study results are available to establish more accurate values." This approach provides a "reasonable RUL estimate without requiring any prior knowledge about the age of the equipment being replaced.[2]

The EUL and RUL specified for this measure are shown below. A fan motor is specified as the host equipment for which the RUL (1/3 of EUL) is based upon.

Effective Useful Life and Remaining Useful Life

Parameter	Value	Source
EUL / RUL (yrs)	15.0 / 5.0	California Public Utilities Commission (CPUC). 2014. "DEER2014-EUL-table-update_2014-02-05.xlsx." DEER EUL ID: Motors-fan
EUL / RUL (yrs)	13.0 / NA	California Public Utilities Commission (CPUC). 2014. "DEER2014-EUL-table-update_2014-02-05.xlsx." DEER EUL ID: ProcDist-Motor_Speed

BASE CASE MATERIAL COST ($/UNIT)

The base case cost for an *add-on equipment installation* is equal to $0 because there are no modifications to the existing equipment.

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[1] California Public Utilities Commission (CPUC). 2016. *Resolution E-4807.* December 16. Page 13.

[2] KEMA, Inc. 2008. "Summary of EUL-RUL Analysis for the April 2008 Update to DEER." Memorandum submitted to Itron, Inc.

[3] San Diego Gas & Electric (SDG&E), Marketing Programs & Planning. 2004. *1994 & 1995 Commercial Energy Efficiency Incentives Ninth Year Retention Evaluation*. Study ID Nos. 925 & 961.

ADM Associates, Inc. 2003. *Southern California Edison Commercial/Industrial/Agricultural Energy Efficiency Incentives Program Retention Study*. Prepared for Southern California Edison Company.

San Diego Gas & Electric (SDG&E). 2003. *1996 & 1997 Agricultural Energy Efficiency Incentives Sixth Year Retention Evaluation*. Study ID Nos. 1000 & 1024.

MEASURE CASE MATERIAL COST ($/UNIT)

For add-on equipment (AOE) measures, the measure cost is the full measure cost (FMC) to purchase and install. FMC is represented by the equation below:

FMC = Measure Case Material Cost + Measure Case Installation Cost

The implementation requirements for this measure are the material and labor for the installation of the VSD and pressure sensor with commissioning. The costs for the VSD were collected using 2019 RS Means9 and are summarized by motor size (hp) below:

Fan Motor (HP)	Material Cost ($)	Installation Cost ($)	Full Measure Cost ($)
10 HP	$3,037	$ 956	$3,992
15 HP	$3,837	$1,396	$5,233
20 HP	$4,637	$1,396	$6,033
25 HP	$5,413	$1,825	$7,238
30 HP	$6,674	$1,825	$8,499
40 HP	$7,644	$1,825	$9,469
50 HP	$10,118	$2,304	$12,422

BASE CASE LABOR COST ($/UNIT)

The base case labor cost for an *add-on equipment installation* is equal to $0 because these are no modifications to the existing equipment. The customer has the option to make no changes to their existing system.

MEASURE CASE LABOR COST ($/UNIT)

See Measure Case Material Cost above.

NET-TO-GROSS

The NTG values were obtained using the DEER READI tool. The relevant NTG values for the measures in this workpaper are in the table below.

Net-to-Gross Ratios

Parameter	Value	Source
Agric- Default>2yrs	0.60	2011 DEER Update Report - Section 15 Table 15-3
IND- Default>2yrs	0.60	2011 DEER Update Report - Section 15 Table 15-3

The net-to-gross (NTG) ratio represents the portion of gross impacts that are determined to be directly attributed to a specific program intervention. These NTG values are based upon the average of all NTG ratios for all evaluated 2006 – 2008 agriculture sector programs, as documented in the 2011 DEER Update Study conducted by Itron, Inc. These sector average NTGs (“default NTGs”) are applicable to all energy efficiency measures that have been offered through agriculture and commercial sector programs for more than two years and for which impact evaluation results are not available.

[9] RS Means 2019 data was collected from Gordan’s online database portal for RS Means. For additional details on the line items #s please reference the Excel Calculation file sheet ‘Measure Cost”

GSIA

The gross savings installation adjustment (GSIA) rate represents the ratio of the number of verified installations of the measure to the number of claimed installations reported by the utility. This factor varies by end use, sector, technology, application, and delivery method. This GSIA rate is the current "default" rate specified for measures for which an alternative GSIA has not been estimated and approved.

Gross Savings Installation Adjustments

Parameter	Value	Source
GSIA	1.0	California Public Utilities Commission (CPUC), Energy Division. 2013. *Energy Efficiency Policy Manual Version 5*. Page 31.

NON-ENERGY IMPACTS

Non-energy impacts for this measure have not been evaluated.

DEER DIFFERENCES ANALYSIS

This section provides a summary of DEER-based inputs and methods, and the rationale for inputs and methods that are not DEER-based.

DEER Difference Summary

DEER Item	Comment / Used for Workpaper
Modified DEER methodology	No
Scaled DEER measure	No
DEER Building Prototypes Used	No
DEER Version	N/A
DEER Run ID	N/A
NTG	Source: DEER 2014. The NTG of 0.60 is associated with NTG ID: Agric- *Default>2yrs*, *Agric-Default>2yrs* IND- *Default>2yrs*, *Agric-Default>2yrs*
GSIA	Source: DEER. The GSIA of 1.0 is associated with GSIA ID: *Def-GSIA*
EUL/RUL	Source: DEER 2014. The value of 15 years is associated with EUL ID: M*otors-fan*.

There are two surveys used for the development of this work paper. The first survey was a web-based (Survey monkey) questionnaire sent to customers between the NAICS code 111000 to 112990 and 31100 to 312140 within PG&E territory and a total of 15 customers responded. The survey was designed to collect data on the facilities' operating hours, production rates, and various fan types used for their operations. Based on the responses of the survey the use of VFDs on baghouses is not a common practice.

A second survey was performed for baghouse vendor and designers to learn about the common installation practices, design parameters, and baghouse sizes for new and existing systems. Based on the vendor outreach, 4 baghouse designers shared insights on the design and selection processes for a variety of parameters. A common theme during these discussions is the custom nature that each system is designed based on their original end-use system operation. All the vendors agreed that they recommend customers to install VFDs on new baghouse systems if the customers have the additional capital.

Based on the result of the surveys, ERI developed correlations between fan motor size to baghouse size and ducting diameter that is used for the development of the energy savings calculations.

ATTACHMENTS

Calculations for SWPR005-01.xlsx

Fan Project Data for SWPR005-01.xlsx

AGR Customer Survey for SWPR005-01.xlsx

REFERENCES

[A] Institute of Electrical and Electronics Engineers (IEEE) Standards Association. 2014. *IEEE Recommended Practice and Requirements for Harmonic Control in Electric Power Systems.* IEEE Std. 519TM -2014. New York (NY): IEEE.

REVISION HISTORY

Measure Characterization Revision History

Revision Number	Revision Complete Date	Primary Author, Title, Organization	Revision Summary and Rationale for Revision
01	09/13/2019	Ethan Clifford, ERI, Randy Kwok (PG&E)	First draft